

# PATENT SPECIFICATION

(11) 1328303

1328303

## DRAWINGS ATTACHED

(21) Application No. 29575/71 (22) Filed 24 June 1971

(44) Complete Specification published 30 Aug. 1973

(51) International Classification H05B 33/12

(52) Index at acceptance

C4S 311 43Y 68X 68Y 709 713 714 731 733 757 768  
76Y 770 78Y

HIK 211 222 271 273 287 312 341 34Y 353 405 42X  
54Y 551 55Y 578 586 591 59Y 619 61Y 625 62Y

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## (54) Ga As DIODE-PHOSPHOR LAMPS

(71) We, STANDARD TELEPHONES  
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pany, of 190 Strand, London, W.C.2., Eng-  
land, do hereby declare the invention, for  
which we pray that a patent may be granted  
to us, and the method by which it is to be  
performed, to be particularly described in and  
by the following statement:—

This invention relates to GaAs diode-  
phosphor lamps and finds particular but not  
exclusive application in the provision of dis-  
play devices such as a seven bar array, or  
other alphanumeric display array, incorporat-  
ing a number of such lamps on a common  
substrate.

Gallium arsenide diodes emit infra-red  
light, but this light can be converted into  
visible light by using a suitable anti-Stokes  
phosphor. Normally such a diode is grown by  
liquid epitaxy, preferably using silicon as a  
dopant because this is an amphoteric dopant  
in gallium-arsenide. A trough to contain the  
phosphor is then etched in the face of the  
semiconductor material so as to encircle a  
small area of the junction. The efficiency of  
such a device is not only limited by the poor  
efficiency of an anti-Stokes phosphor but also  
by the fact that a significant proportion of  
the infra-red recombination radiation is wasted  
in that it never reaches the phosphor. One of  
the factors contributing to this waste is the  
amount of light radiated at a significant angle  
to the junction. This invention is concerned  
with a method of construction which will  
provide a measure of optical guiding in order  
to channel a proportion of this otherwise  
wasted radiation so that it will reach the  
phosphor and hence be able to make a con-  
tribution to the production of useful visible  
radiation.

According to the invention there is pro-  
vided a gallium arsenide diode-phosphor  
lamp wherein the recombination region of the  
gallium arsenide diode lies in a region of  
gallium arsenide which is sandwiched between  
two layers of gallium aluminium arsenide.

The efficacy of the gallium aluminium  
arsenide layers in providing the desired  
channeling effect relies upon the fact that it  
has a lower refractive index than gallium  
arsenide. There is thus a critical angle at each  
heterojunction, and light incident upon either  
of the gallium aluminium arsenide layers at  
an angle greater than this critical angle is  
totally internally reflected. This totally inter-  
nally reflected light is thus trapped in the  
recombination region of gallium arsenide and  
is ducted to the perimeter of the region where  
it can be absorbed by the phosphor.

There follows a description of a seven bar  
array incorporating a number of gallium  
arsenide diode-phosphor lamps on a single  
substrate, these lamps embodying the inven-  
tion in a preferred form. The description  
refers to the accompanying drawings in  
which:—

Figure 1 depicts a diagrammatic sectional  
view across the width of one of the bar-  
shaped lamps of the array, and

Figure 2 depicts a plan view showing the  
arrangement of the lamps to form a seven bar  
array.

The method of manufacture involves the  
growth by liquid epitaxy of four layers 1, 2,  
3 and 4 upon an n-type gallium arsenide  
substrate 5; layer 2 is approximately 10  
microns thick, but the thickness of the other  
layers is not critical. The first layer to be  
grown, layer 1, is an n-type layer of gallium  
aluminium arsenide having approximately 50  
mol% substitution of aluminium  
(Ga<sub>0.5</sub>Al<sub>0.5</sub>As). The next layer to be grown,  
layer 2, is a layer of gallium arsenide. This  
layer is to contain the recombination region  
and hence requires a transition from n-type  
material to p-type material. In the growth  
of this layer use is made of the amphoteric  
doping properties of silicon in gallium  
arsenide. Accordingly while this layer 2 is  
grown the temperature is caused to fall through  
the range 910° C to 880° C so that the first  
part grows in n-type form and the last part in

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p-type form with a continuous graduation between them through a compensated region. The third and fourth layers 3 and 4 are respectively p-type layers of gallium aluminium arsenide ( $\text{Ga}_{0.9}\text{Al}_{0.1}\text{As}$ ) and gallium arsenide.

5 The material is then polished, contact layers 6 and 7 are put on, and standard photolithographic techniques are used to etch a number of channels through all the epitaxially grown  
10 layers. These channels delineate small strips 8 of grown material arranged in the form of a seven bar array. The channels are then filled with an anti-Stokes phosphor 9 comprising  
15 erbium and ytterbium activators in a lanthanum fluoride matrix material.

WHAT WE CLAIM IS:—

1. A gallium arsenide diode-phosphor lamp wherein the recombination region of the gallium arsenide diode lies in a region of gallium  
20 arsenide which is sandwiched between two layers of gallium aluminium arsenide.

2. A lamp as claimed in claim 1 wherein the phosphor is contained in a trough encircling a region of the junction between the  
25 diode's regions of different conductivity type.

3. A lamp as claimed in claim 1 or 2 wherein the layers or gallium aluminium arsenide have a 50 mole% substitution of aluminium so that they satisfy the formula  $\text{Ga}_{0.9}\text{Al}_{0.1}\text{As}$ .

4. A lamp as claimed in any preceding claim wherein silicon is used as an amphoteric dopant is forming the junction between the diode's regions of different conductivity type.

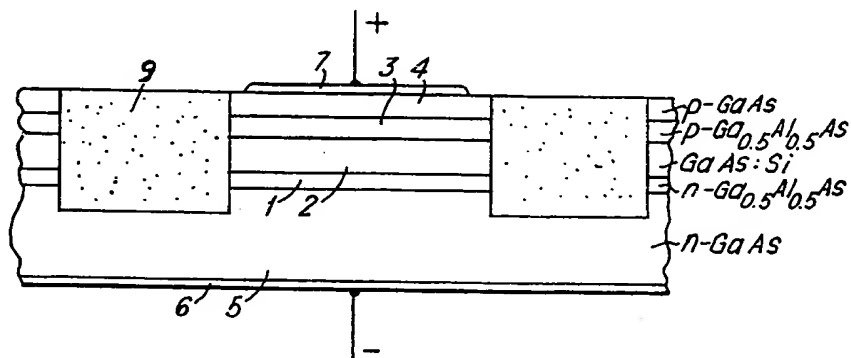
5. A plurality of lamps as claimed in any preceding claim constructed upon a single substrate.

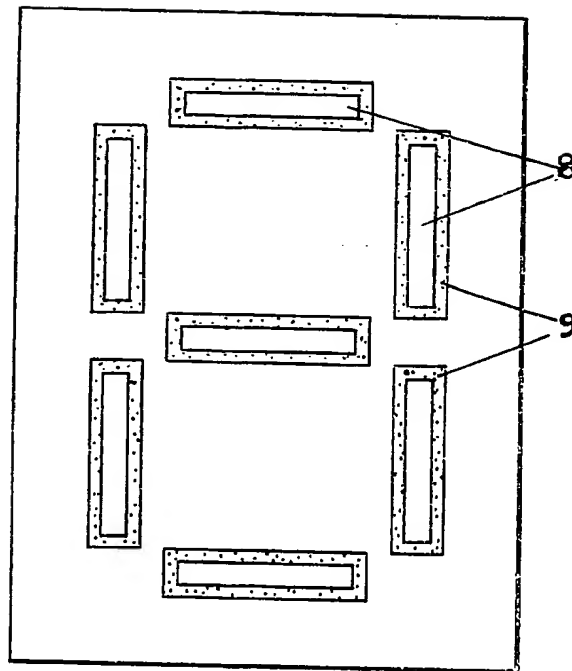
6. A plurality of lamps as claimed in claim 5 and arranged in the form of an alphanumeric display device.

7. A gallium arsenide diode-phosphor lamp substantially as hereinbefore described with reference to the accompanying drawings.

8. An alphanumeric display device substantially as hereinbefore described with  
45 reference to the accompanying drawings.

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Fig. 2